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6. AUTHOR(S) DR RICHARD PASTORE					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) State University of New York Cognitive & Psycholinguistic Dept P.O. Box 6000 Binghamton NY 13902-6000				8. PERFORMING ORGANIZATION REPORT NUMBER	
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13. ABSTRACT (Maximum 200 words)

The research supported under the parent grant investigated the nature and integration of auditory features which are assumed to be extracted at lower levels of all perceptual processing. The next level of perceptual processing, and the classes of perceptual errors, are well documented for vision, but have not been examined for audition. The AASERT research was based upon findings from the parent project, but investigated perceptual processes which are complimentary and supplement the focus of the parent project. Because feature integration processes are very sensitive to the availability of attentional resources, and limits on those resources, the investigated perceptual processes are extremely critical to applied situation where stress and task demands may be great and where errors are costly. In addition to conduct of meaningful basic research (with significant, practical human factors implications), the project provided important training opportunities for future scientists.

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1. COVER PAGE

Final Progress Report

July 1, 1993 - June 31, 1997

Perception of Auditory Events: Attentional Limitations

Grant Number:	F49620-93-1-0327
Principal Investigator:	Richard E. Pastore
Institution:	Binghamton University (State University of New York) Binghamton, NY 13902-6900

2. OBJECTIVES

The research supported under the parent grant investigated the nature and integration of auditory features which are assumed to be extracted at lower levels of all perceptual processing. The next level of perceptual processing, and the classes of perceptual errors, are well documented for vision, but have not been examined for audition. The AASERT research was based upon findings from the parent project, but investigated perceptual processes which are complimentary and supplement the focus of the parent project. Because feature integration processes are very sensitive to the availability of attentional resources, and limits on those resources, the investigated perceptual processes are extremely critical to applied situation where stress and task demands may be great and where errors are costly. In addition to conduct of meaningful basic research (with significant, practical human factors implications), the project provided important training opportunities for future scientists.

3. STATUS OF EFFORT

The two major goals of the AASERT effort were (1) the conduct and completion of modern basic research on higher level processes in auditory perception and (2) the training, as part of defense-sponsored research, of promising young students who are likely to become our high quality scientists of the future. The completed research investigated the nature and role of attention in the processing of acoustic signals. One set of experiments has demonstrated the direct application of feature integration theory, originally developed for vision, to the processing of acoustic; if anything, the findings are stronger for auditory than for visual features. A second set of experiments investigated the nature of attentional or capacity limitations on the processing of features for different classes of acoustic stimuli ranging from music and speech to other types of natural stimuli. The findings from both sets of research experiments have been described in several manuscripts which have been published, are under review, or are in the final stages of preparation, as well as in a number of meeting presentations.

The training of future scientists also has been very successful. Students previously trained on the project now hold important scientific positions. Graduate, and some undergraduate, students trained under this grant have been authors or co-authors on a significant number of professional publications and presentations; the undergraduate students also have prepared and presented posters at campus research fairs. All of the undergraduates associated with the project have been involved with every aspect of the basic research and currently are either in graduate school or in the process of applying to graduate school for further scientific training. The graduate students who worked the project received both basic and applied research training; nearly all either have or are seeking professional scientific positions.

4. ACCOMPLISHMENTS / NEW FINDINGS

Concepts of attentional processes and capacity limitations, most developed in research with complex visual stimuli, have been demonstrated to apply to the perception of complex auditory stimuli, at least when conceptually important differences between the human auditory and visual systems are carefully considered. Pastore & Crawley (in press) provide evidence that the

modeling of human perception needs to carefully evaluate the nature and interaction of human perceptual capabilities, and not simply assume that human perception largely reflects the physical attributes of complex stimuli. Hall, Pastore, Huang, & Acker (in press) demonstrated that feature integration notions, including the existence of the illusory conjunction of presented stimulus features, occur with relatively high frequency in the perception of complex auditory stimuli. Acker and Pastore (1996a; also in preparation) provide an important mapping of basic perceptual features from physical dimensions, as well as the conditions in which sensory feature information and higher level attentional factors interact in defining the manner in which complex stimuli are perceptually organized. Crawley, Acker, and Pastore (in preparation) provide evidence that perception in expert and inexperienced listeners exhibits similar dependencies on sensory and attentional factors, with the experts simply being more efficient and effective at encoding and processing complex stimuli. All of these findings are important predicting the probable occurrence of important perceptual errors for work to design auditory information signals of any kind as well as in the development of virtual auditory displays.

Farrington and Pastore (1996) and Crawley, Pastore, and Hinds (under review) have demonstrated the applicability of perceptual principles and limitations, originally defined for simple laboratory stimuli, to our understanding of limits on the perception of complex stimuli under more typical listening conditions. In doing so, this research has defined the types of modifications required to utilize basic laboratory results in applied situations. In addition to higher stimulus limits reflecting greater stimulus variability under non-laboratory listening conditions, other (now identified) perceptual factors need to be considered. Thus, for example, tones whose duration (thus spectral bandwidth) and frequency separation yield high levels of discriminability in the laboratory (even in the presence of broad band masking noise) can be indistinguishable when presented in the context of certain stimulus environments which contain no energy in the frequency region (critical band) of the tones, yet these same stimuli may be made even more discriminable in the context of contrasting stimuli adding energy to that frequency region. The important consideration is whether the stimulus context provides an enhanced or diminished perceptual contrast with the stimuli to be discriminated; the analysis of the contrast requires a consideration of perceptual, rather than simply sensory, demands. Thus, principles of perception transcend lower level sensory limitations and need to be considered along with sensory limitations in evaluating auditory perception in any non-laboratory environment.

Realistic listening is based upon the perception of complex perceptual categories, rather than the simple detection or discrimination of sinusoidal stimuli typical of most laboratory research. However, very little research other than speech has evaluated the perception of complex categories. Our research, including that described in the previous paragraph, has evaluated perception of other types of complex categories of acoustic stimuli, including speech. In the perception of speech, research by Kuhl and associates has demonstrated that the category prototype function as a type of perceptual magnet, reducing discriminability relative to other stimuli within the category. Completed research demonstrated that the prototype for a known classes of nonspeech (musical chords) operates as a type of perceptual anchor (Acker, Pastore, & Hall, 1995), and thus in a fashion opposite to a perceptual magnet, at least for experts (musicians). The experts also exhibit asymmetric integrality for what typically are assumed to be independent or separable physical dimensions (Acker & Pastore, 1996b). Untrained listeners (nonmusicians) do not exhibit evidence for a strong prototype for such chord categories. Finally, work initiated under the project (e.g., Farrington & Pastore, in preparation) has begun to define

the most effective strategies for the learning or training, as well as the subsequent generalization, of categories for various types of complex acoustic stimuli. These research efforts are enabling science to understand the conditions in which basic findings using simple stimuli in the laboratory can be effectively generalized to real applied situations.

5. PERSONNEL AFFILIATED and SUPPORTED

A. FACULTY:

Richard E. Pastore, Ph.D., Project Director

B. SUPPORTED GRADUATE STUDENT:

Barbara E. Acker received her M.A. and M.M. while working under the project and is expected to receive her Ph.D. in May 1998. While working on the project, she also received applied training through Loral and Lockheed-Martin, working on DoD projects (e.g., Navy LAMPS). She currently is seeking a post-doctoral research position.

Edward J. Crawley joined the project with an M.A. from a different institution. He anticipates completion of his Ph.D. in May, 1999.

Shannon M. Farrington completed his M.A. under the project, gaining applied experience through Loral and IBM. He has now accepted a position in human usability and product development with IBM in San Jose, California.

Michael D. Hall worked on initial aspects of the project prior to receiving his Ph.D. He currently holds a post-doctoral research position at the University of Washington, Seattle.

Wenyi Huang earned his M.A. shortly after the beginning of this project. He received additional training from our University's engineering program, and currently is employed by a major IMB subcontractor in Charlotte, NC.

James W. Liberto worked for two years on aspects of the project. Based upon a lack of compatibility between his skills / interests and those of the project and laboratory, his transfer to a different graduate program was encouraged. He currently is enrolled in an engineering program at our university.

Michael Skelly joined our research staff near the end of the project, having received his B.A. from another institution. He is anticipated to complete his M.A. in May 1999.

C. UNDERGRADUATE STUDENT PARTICIPANTS:

Kevin J. Hinds received training through the project prior to receiving his B.A.; his a co-author on a manuscript currently under review. He is now a graduate student at another institution.

Tracy Samuel and **Kelly Straeger** both worked on the project prior to receiving their B.A. degrees and entering graduate school at other institutions.

Linda Choi received project training prior to earning her B.S. degree. She currently is in optometry school.

James Rao and **Trish Widmer** both received training on the project prior to receiving B.A. degrees last year, with Trish presenting an undergraduate conference poster based upon project research. Both have taken this year off to earn money to support their continuing graduate education; both currently are applying to graduate school.

Melissa Vindigni, **Christina Shu**, and **Tina Proust** worked on various aspects of the project over the last two years; Melissa and Tina presented undergraduate conference posters based upon project research. All three are expected to receive their B.A. in May, 1998, and currently are applying to graduate school.

Shawn Weil, with the exception of a semester at Oxford University, has worked on laboratory projects for the last two years. He is co-author on one manuscript in preparation, has presented a poster on project research, and is currently completing an Honors Thesis project developed in Laboratory building upon other project research. In addition to applying for a National Science Foundation predoctoral research fellowship, he is in the process of applying to graduate school in auditory perception. His B.A. will be awarded in May, 1998

Bret Goldberg and **Steven Nadel** began working on the project earlier this year and are currently involved with research which grew out of the project. Both are expected to earn their B.A. degrees in 1999.

6. PUBLICATION OF AASERT RESEARCH

Bold print indicates student affiliated with AASERT Project.

A. Manuscripts Published or In Press (all peer reviewed)

Acker, B.E., & Pastore, R.E. (1996). Melodic perception in homophonic and polyphonic contexts. In B. Pennycook & E. Costa-Giomi (Eds.) **Proceedings of the Fourth International Conference on Music Perception and Cognition** (pp.453-458). Montreal: Faculty of Music, McGill University.

Acker, B.E. & Pastore, R.E. (1996). Perceptual integrality of major chord components. **Perception & Psychophysics**, **58**(5), 748-761.

Acker, B.E., Pastore, R.E., & **Hall**, M.D. (1995). Within-category discrimination of musical chords: Perceptual magnet or anchor? **Perception & Psychophysics**, **57**(6), 863-874.

Hall, M.D., Pastore, R.E., **Huang**, W. & **Acker**, B.E. (in press). Auditory feature integration theory for musical tones. **Perception & Psychophysics**.

Li, X., & Pastore, R.E. (1995). Perceptual constancy of a global spectral property: Spectral slope discrimination. **Journal of the Acoustical Society of America**, **98**(4), 1956-1968.

Pastore, R.E., & **Crawley**, E., (in press) Locus Equations: Assumptions and dependencies **Behavioral & Brain Sciences**

Pastore, R.E., & **Farrington**, S.M. (1996). Measuring the Difference Limen for identification of order of onset for complex auditory stimuli. **Perception & Psychophysics**, 58(4), 510-526.

Pastore, R. E. (in press). Some modern speech phenomena may be less than current beliefs. In J. Charles-Luce, P. Luce and J. R. Sawusch (Eds.), **Theories in Spoken Language: Perception, Production, and Development**. Norwood. NJ: Ablex.

B. Manuscripts Under Review

Acker, B.E., & Pastore, R.E. (under review). Musicians show an "anchor effect" for a major chord prototype, non-musicians do not. **Perception & Psychophysics**.

Crawley, E.J., Pastore, R.E. & **Hinds**, K.J. (under review). Auditory temporal order thresholds for dichotic listening conditions. **Perception & Psychophysics**.

C. Manuscripts Under Revision or Nearing Completion

Acker, B.E., & Pastore, R.E. (submission pending). Asymmetric integrality in musical chords: Spectral versus musical relation?. **Perception & Psychophysics**.

Acker, B.E., & Pastore, R.E. (submission pending). Effects of timbre manipulations on melody perception, **Perception & Psychophysics**.

Crawley, E., **Acker**, B.E., Pastore, R.E. (submission pending). Perception of multivoiced music: compositional style and task demands. **Perception & Psychophysics**.

Farrington, S.M., & Pastore, R.E. (submission pending). Perceiving source characteristics from complex natural sounds: Walker identification. **Journal of Experimental Psychology: Human Perception & Performance**.

Pastore, R.E., **Huang**, W., & **Hall**, M.D. (under revision). The Octave Illusion: Exploring a common variant. **Perception & Psychophysics**.

D. Manuscripts In Preparation (research completed, manuscript being written)

Cho, J.L., **Hall**, M.D., & Pastore, R.E. Instrument timbre in the perception of musical chords.

Hall, M.D. & Pastore, R.E. Defining features of steady-state timbres.

Hall, M.D., & Pastore, R.E. Effects of stimulus complexity on the perceptual organization of musical tones.

7. INTERACTIONS & TRANSACTIONS

A. Published Abstracts of Meeting Presentations

Acker, B.E. (1996). Compositional style, frequency height, and harmonic influences on melody perception. **Journal of the Acoustical Society of America**, 100(4, pt. 2), 2844. (Joint meeting of the Acoustical Society of America and Acoustical Society of Japan, Honolulu, December, 1996. Paper presentation).

- Acker, B.E., & Pastore, R.E. (1997). Effects of timbre manipulations on melody perception. **Journal of the Acoustical Society of America**, 101(5, pt. 2), 3167. (Meeting of the Acoustical Society of America, State College, PA, June, 1997. Paper presentation).
- Acker, B.E., & Pastore, R.E. (1996). Directed attention and the perception of frequency changes. **Journal of the Acoustical Society of America**, 99(4, pt. 2), 2482. (Meeting of the Acoustical Society of America, Indianapolis, May, 1996. Paper presentation).
- Acker, B.E., & Pastore, R.E. (1996). Integrality of first inversion C-major chord components. **Journal of the Acoustical Society of America**, 99(4, pt. 2), 2481. (Meeting of the Acoustical Society of America, Indianapolis, May, 1996. Paper presentation).
- Acker, B.E., Pastore, R.E., & Hall, M.D., (1994) Within-category discrimination of musical chords: Perceptual magnet or anchor? **Journal of the Acoustical Society of America**, 95, 2937. (Meeting of the Acoustical Society of America, Cambridge, MA, May, 1996. Paper presentation).
- Crawley, E.J., Acker, B.E., & Pastore, R.E. (1997). Ability to detect changes in musical pieces is a function of musical training and musical context. **Journal of the Acoustical Society of America**, 101(5, pt. 2), 3166. (Meeting of the Acoustical Society of America, State College, PA, June, 1997. Paper presentation).
- Farrington, S.M., & Pastore, R.E. (1996). Perceiving source characteristics from complex sounds. **Journal of the Acoustical Society of America**, 99(4, pt. 2), 2598. (Meeting of the Acoustical Society of America, Indianapolis, IN, May, 1996. Paper presentation).
- Pastore, R.E., & Crawley, E.J. (1996). Dichotic temporal order thresholds. **Journal of the Acoustical Society of America**, 99(4, pt. 2), 2598. (Meeting of the Acoustical Society of America, Indianapolis, IN, May, 1996. Poster presentation).
- Pastore, R.E., Farrington, S.M., & Acker, B.E. (1994) Exploration of the phonetic structure of cues for place of articulation. **Journal of the Acoustical Society of America**, 95, 2976. (Meeting of the Acoustical Society of America, Cambridge, MA, May, 1996. Poster presentation).
- Pastore, R.E., Liberto, J. W. & Crawley, E.J. (1996). Mapping multidimensional perceptual consonant space for place contrasts. **Journal of the Acoustical Society of America**, 100(4, pt. 2), 2694. (Joint meeting of the Acoustical Society of America and Acoustical Society of Japan, Honolulu, December, 1996. Poster presentation).

B. Other Meeting Presentations

- Acker, B.E., & Pastore, R.E. (1996). Melodic perception in homophonic and polyphonic contexts. **Fourth International Conference on Music Perception and Cognition**, Montreal, P.Q., Canada (Paper presentation).
- Acker, B.E., & Pastore, R.E. (1995) Major chord prototypes are based on just temperament. **American Psychological Society**, NY, NY. (Poster presentation).
- Crawley, E.J. & Acker, B.E. & Pastore, R.E. (1997). Effects of training and task demands on the detection of single note changes in music **Psychonomic Society**, (Poster presentation).

Farrington, S.M. & Pastore, R.E. (1995) Auditory temporal order identification: A discrimination analysis. **American Psychological Society**, NY, NY. (Poster Presentation).

Hall, M.D., & Pastore, R.E. (1993). An Auditory Analog to Feature Integration. **Psychonomic Society**, Washington, D.C., Nov., 1993 (Poster Presentation).

C. Consultative & Advisory Functions:

Richard E. Pastore

Consulting Editor, **Perception & Psychophysics**

Extramural Personnel Reviewer: Tenure, Promotion to Associate Professor, Promotion to Full Professor (Institutions named upon request)

Ad hoc reviewer for peer review journals: **Journal of the Acoustical Society of America** (Psychological acoustics, Speech Communication), **Perception & Psychophysics**, **Psychological Science**.

Barbara Acker & Richard Pastore:

Organized a special session on Music and Speech Perception for the May, 1996 meeting of the Acoustical Society of America, Indianapolis, Indiana.

D. Transactions:

a. Former Ph.D. graduate students:

Michael Hall is now on a postdoctoral fellowship at the University of Washington

Sheldon Li is a research scientist at AT&T Bell Laboratories.

b. Former M.A. Students:

Shannon Farrington is now employed in Human Factors at IBM San Jose, CA.

Wenyi Huang is now employed by an IBM subcontractor in Charlotte, North Carolina

James Liberto has entered a different graduate program.

c. Current Ph.D. Graduate Students:

Barbara Acker has been awarded a Dissertation Year Fellowship to finish up her Ph.D. requirements. She worked part time this past year in Human Factors for Lockheed Martin on the Navy LAMPS Helicopter project. This work involves the direct application of basic research findings in an important, applied setting. Ms. Acker also has served as an ad hoc peer reviewer for **Perception & Psychophysics**.

Edward Crawley holds a research position in the laboratory while working toward his Ph.D. dissertation research.

c. Current M.A. Graduate Students:

Michael Skelly joined the laboratory staff shortly before the end of the AASERT project.

8. NEW DISCOVERIES, INVENTIONS, PATENT DISCLOSURES

No inventions or patent disclosures.

9. HONORS AND AWARDS

A. Past Year:

Consulting Editor, **Perception & Psychophysics**.

B. Lifetime:

Fellow, American Psychological Association, Division 3.

Fellow, American Psychological Society.